Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

FLUE TEMPERATURE PROGRAMS FOR THE CARBOLITE AND OTTAWA 310-mm PILOT COKE OVENS

J.F. Gransden, J.T. Price and S. Seto

December 1982

This document is an unedited **interim report** prepared primarily for discussion and limited reporting purposes. It does not represent a final expression of the opinion of the Canada Centre for Mineral and Energy Technology **(CANMET)**

Ce document est un **rapport** préliminaire non révisé et rédigé principalement en vue d'une discussion restreinte et de la documentation interne. Il ne représente nullement l'opinion définitive du Centre canadien de la technologie des minéraux et de l'énergie **(CANMET)**

14 pp

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
DIVISION REPORT ERP/ERL 82-57(TR)

OCT 3 1983

MICROMEDIA

FLUE TEMPERATURE PROGRAMS FOR THE CARBOLITE AND OTTAWA 310-mm PILOT COKE OVENS

by

J.F. Gransden*, J.T. Price** and S. Seto***

ABSTRACT

Two of CANMET's pilot coke ovens have heating walls constructed of silicon carbide brick, a material that has a thermal conductivity considerably higher than silica brick used in the construction of industrial ovens. Flue temperatures of these pilot ovens must therefore be made to vary throughout the coking cycle so they simulate the heat transfer that occurs in an industrial oven. A mathematical model of a coke oven has been used to derive a number of such temperature-time programs so the pilot ovens can be operated at different coking rates.

---

*Research Scientist, **Carbonization Research Section Head, Combustion and Carbonization Research Laboratory, CANMET, Department of Energy, Mines and Resources, Ottawa. *** Former student Department of Chemical Engineering, University of Ottawa, now employed by Ontario Hydro.

PROGRAMMES SUR LA TEMPÉRATURE DE FOYER POUR LE FOUR À COKE PILOTE POUR LA CARBOLITE ET CELUI SITUÉ À OTTAWA

par

J.F. Gransden*, J.T. Price** et S. Seto***

RÉSUMÉ

Deux des fours à coke pilotes du CANMET ont des parois thermiques construites de briques de carbure de silicium utilisées dans la construction de fours industriels. On doit, par conséquent, faire varier la température dans les foyers de ces fours pilotes au cours du cycle de cokéfaction afin de simuler le transfert thermique qui se produit dans les fours industriels. On a utilisé un modèle mathématique de four à coke pour dériver un grand nombre des programmes température-temps afin de pouvoir faire fonctionner les fours pilotes à différentes vitesses de cokéfaction.

---

*Chercheur scientifique, **Chef de la section de recherche sur la carbonisation, Laboratoire de recherche sur la combustion et la carbonisation, CANMET, Énergie, Mines et Ressources, Canada, Ottawa. ***Ancien étudiant, département du génie chimique de l'Université d'Ottawa, maintenant employé d'Hydro Ontario.

FOREWORD

This report is a summary of methods and results of work performed by S. Seto for a thesis submitted in partial fulfillment of the requirement for the degree of Bachelors of Applied Science in the Department of Chemical Engineering, University of Ottawa. Dr. B.C.Y. Lu of the University of Ottawa was an advisor and the work was performed at CANMET under the direction of the authors of this report. This synopsis has been prepared to allow easy reference to and wider distribution of the results. Further details may be found in the original thesis available from the authors.

INTRODUCTION

Industrial coal is carbonized in coke ovens which have silica brick heating walls. Gases are burnt in flues on one side of the wall and the heat is transferred through the wall to the coal. Silica suffers little deformation under load at high temperatures until its softening point is reached. Unfortunately the thermal conductivity of silica brick is not high, but it is maximized in coke oven brick by reducing the porosity to a minimum (high-density silica brick). Such brick must be heated and cooled slowly and evenly to avoid cracking in some critical temperature ranges where crystallographic transformations are occurring. This is of little consequence to a battery of industrial ovens which normally will not be cooled down until they are dismantled at the end of their 25-30 year operating life. However, pilot-scale ovens like the ones operated by CANMET, which coke 250-350 kg of coke, frequently need repair and maintenance because of the extreme conditions under which they are often operated (high coking pressure, high coking rate). Repair is easier on a cold oven but if silica brick is used a one week cooling and one week reheating schedule is required, as with CANMET's 460-mm Ottawa test oven. In two CANMET ovens (and others elsewhere) this problem is overcome by building the heating walls of silicon carbide brick, which allows them to be heated and cooled in one day. However, this introduces a further problem as the thermal conductivity of silicon carbide is almost ten times that of silica.

Flue temperatures are fairly constant in industrial ovens. When operated at a constant flue temperature, the Ottawa 460-mm test oven is expected to closely simulate the heat transfer into the coal charge which occurs in an industrial oven as the brick and its thickness is similar. The flue temperatures of the silicon carbide ovens, however, must be programmed to change with time as silicon carbide is a better conductor of heat and the bricks used are thinner. Both ovens are electrically heated so temperature-time programs are easy to implement but their form is difficult to deduce. Obviously the amount of heat entering the coal in the silicon carbide oven must be limited at the beginning of the coking cycle by maintaining the wall at a comparitively low temprature. The temperature-time programs presently used on the two ovens are linear and were formulated from experience at CANMET and elsewhere. The only criterion used was that the temperature in the centre

of the charge should reach a specified value in a specified time. This is unsatisfactory as an infinite number of programs could be used to achieve this goal, but only one would simulate the rate of heat flow into the coal expected in a typical industrial oven. This rate may be expected to influence the way the coal is coked and hence the physical properties of the coke produced which is the primary reason for testing coal in such an oven. The linear programs now in use are thought to be fairly realistic and not to unduly influence the conclusions of test results.

The problem becomes more acute when it becomes necessary to change the coking rate of the ovens, that is the time required to reach a specified temperature, usually 900°C, at the charge centre. This occurs when foundry coke is to be made (long coking time) or when R & D projects require results of varying the coking rate; a recent example was the investigation of the effect of oven productivity on coking pressure and coke quality (1). Even after restricting consideration to linear programs, there are three parameters that can be independently chosen, the start temperature of the program, the rate of linear increase, and the final temperature. A number of tests have been of limited use as the target coking times were badly missed.

In this report temperature-time programs derived from computer modelling of coke ovens is presented for the two CANMET ovens. Their use should overcome the problems discussed above.

METHODS AND RESULTS

The mathematical model of a coke oven developed by Merrick was used (2). This model describes the main chemical and physical changes occurring during carbonization and then provides a computational procedure for predicting the temperature history of the charge. The only input information required is the ultimate chemical analysis of the coal and the oven operating conditions. The coal analysis chosen was that of a typical Canadian industrial blend shown in Table 1 together with the required oven parameters and oven operating conditions, Table 2.

The Carbolite oven used was a silicon carbide oven with a width of 460-mm operated by CANMET at the Coal Research Laboratory in Edmonton. Using the normal temperature-time program for this oven, the computer model predicts

Table 1 - Coal and oven parameters

Carbon	86.9%	ash	6.5%
Hydrogen	5.7%	moisture	3.0%
Oxygen	4.6%		
Nitrogen	1.7%		
Sulphur	1.1%		
	100%		

Table 2 - coal bulk density 817 kg/m^3

		Carbolite	Ottawa 310-mm	Industrial oven
Oven width m	m	0.460	0.310	0.460
Wall thickness	m	0.033	0.051	0.115
Wall material		silicon carbide	silicon carbide	silica
Wall conductivity	W/m	16.2	16.2	1.85
Apecific heat	J/Kg.K	1200	1200	1200
Wall density	Kg/m^3	2640	2640	1922
Start temperature	°6	875	900	constant
rate	°C/h	15	19.5	temp.
Stop temperature	°6	1130	1070	

a coking time of 14.1 hours to a centre temperature of 900°C. In an actual test a time of 14.3 hours was recorded. The model predicts that to obtain this coking time in an industrial oven, that is one with silica bricks having a thickness of 0.115 m, a constant flue temperature of 1271°C would be required. In contrast if a constant temperature was used in the Carbolite oven to obtain the same coking time it would only be 948°C.

Using the model, the variation of the heat flux across the wall/coal interface with time was determined for the silica oven operated at 1271°C and for the Carbolite with its normal time-temperature programs. They are compared in Fig. 1 by plotting the percentage difference in heat flux. The Carbolite passes significantly more heat through its walls at the beginning of the coking cycle and somewhat less at the end.

A new program for the Carbolite oven was derived in the following manner. The required heat flux/time relationslhip at the wall/coal interface of tne Carbolite oven is simply that occurring at the wall/coal interface of the silica oven. Using a heat conduction equation for the silicon carbide brick the relationship was converted to a temperature-time relationship on the flue side of the brick. The result is plotted in Fig. 2 along with the linear program normally used.

It can be seen that the new program should commence at 1271°C and drop extremely rapidly to a temperature somewhat below 850°C before rising again. Tne hign starting temperature is understandable as it is the inside wall temperature of the silica oven and immediately after charging the heat transfer to tne coal will be very high (but it drops very rapidly because of the relatively poor conductivity of the silica brick). It is not practical to program the silicon carbide oven for such a dramatic temperature change in such a short time (about 5 minutes), so the new program was further revised by extraplating it to zero time (solid line in Fig. 2). The heat flux at the wall/coal interface when the revised new program is used is compared with that for the silica oven in Fig. 3. The marked improvement compared to the linear program of Fig. 1 is apparent, and the new program is considered satisfactory.

The same methods were used to derive programs that give different coking times to 900°C and these are shown in Fig. 4. The time against each line is the gross coking time which is the time to 900°C plus a 3 hour "soaking" period. It is apparent that changing the coking rate of a programmed silicon carbide oven involves changing the starting temperature and the rate of temperature increase and that the latter is not linear. It may not be necessary to incorporate into the program all of the final steep temperature rise that occurs near the end of the program. The centre-temperature has reached 900°C before this occurs so the coke has its final physical form. (However, certain properties, coke reactivity for example may be dependent on the maximum temperature the coke has reached, but at present this is unproved.) The steep rise reflects the comparitavely high flue temperatures of a silica brick oven and the coke approaching this temperature.

Temperature programs for the Ottawa 310-mm silicon carbide oven were obtained in a similar manner and are shown in Fig. 5.

CONCLUSIONS AND RECOMMENDATIONS

Temperature-time programs for CANMET'S two silicon carbide ovens have been derived from a computer coke oven model. The programs simulate the heat transfer expected in industrial silica brick ovens. It is recommended that:

1. The programs be used henceforth in R & D projects that require coal to be coked at different coking rates in these ovens.
2. The old linear program and the new program which gives the same coking rate would be tested on three or four coals and the coke properties compared. Consideration should then be given to adopting the new program as standard.

REFERENCES

1. Price, J.T. and Gransden, J.F. "The effect of heating rates on productivity, coke quality and coking pressures from conventially and partially briquetted charges carbonized in CANMET's pilot-scale coke ovens"; Division Report ERP/ERL 82-50(TR).

2. Merrick, D. "Metallurgical coke manufacture: a mathematical study"; PhD thesis, London University; 1977.

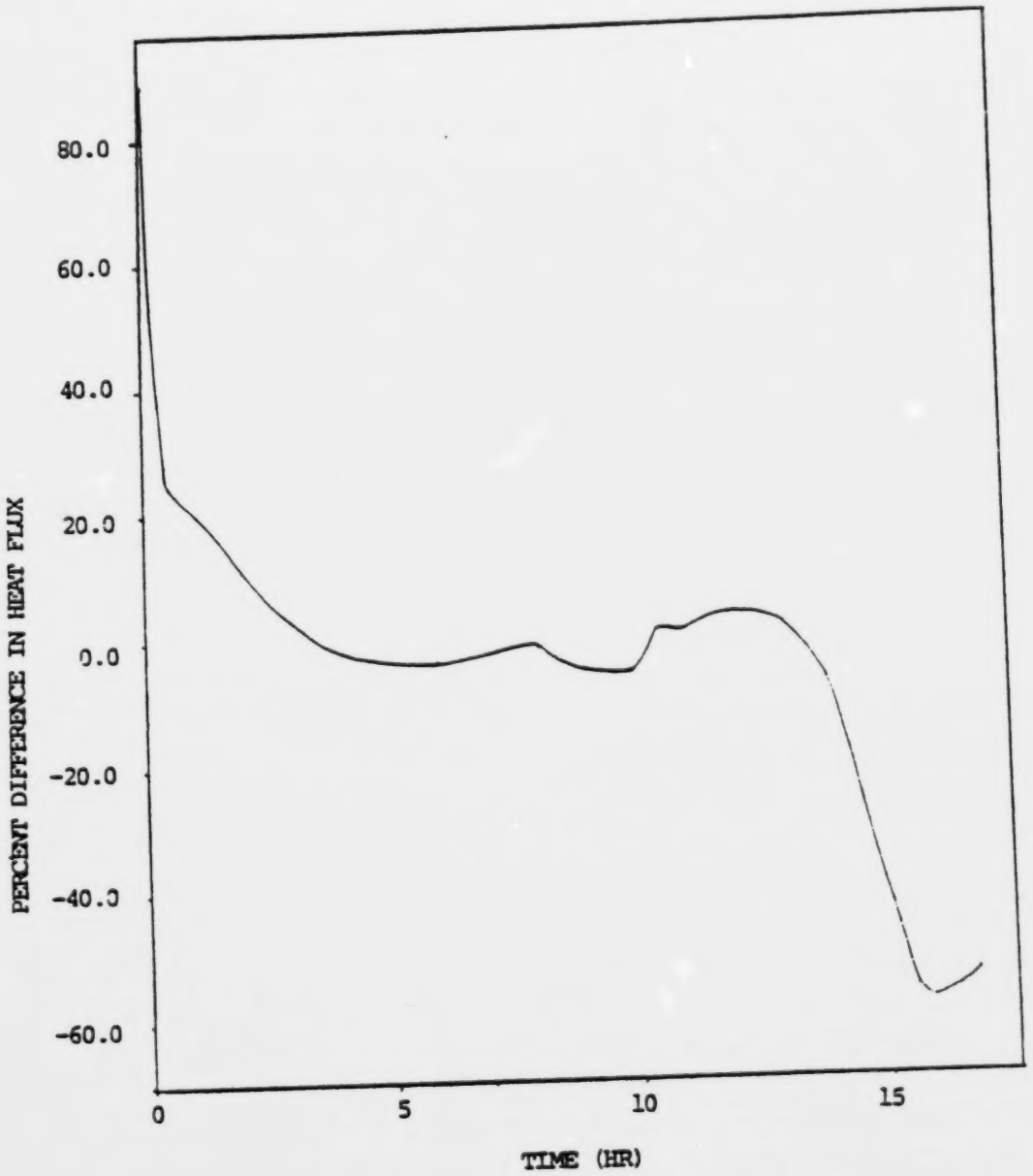

Fig. 1 - Comparison of heat flux in carbolite oven and typical industrial oven as predicted by model

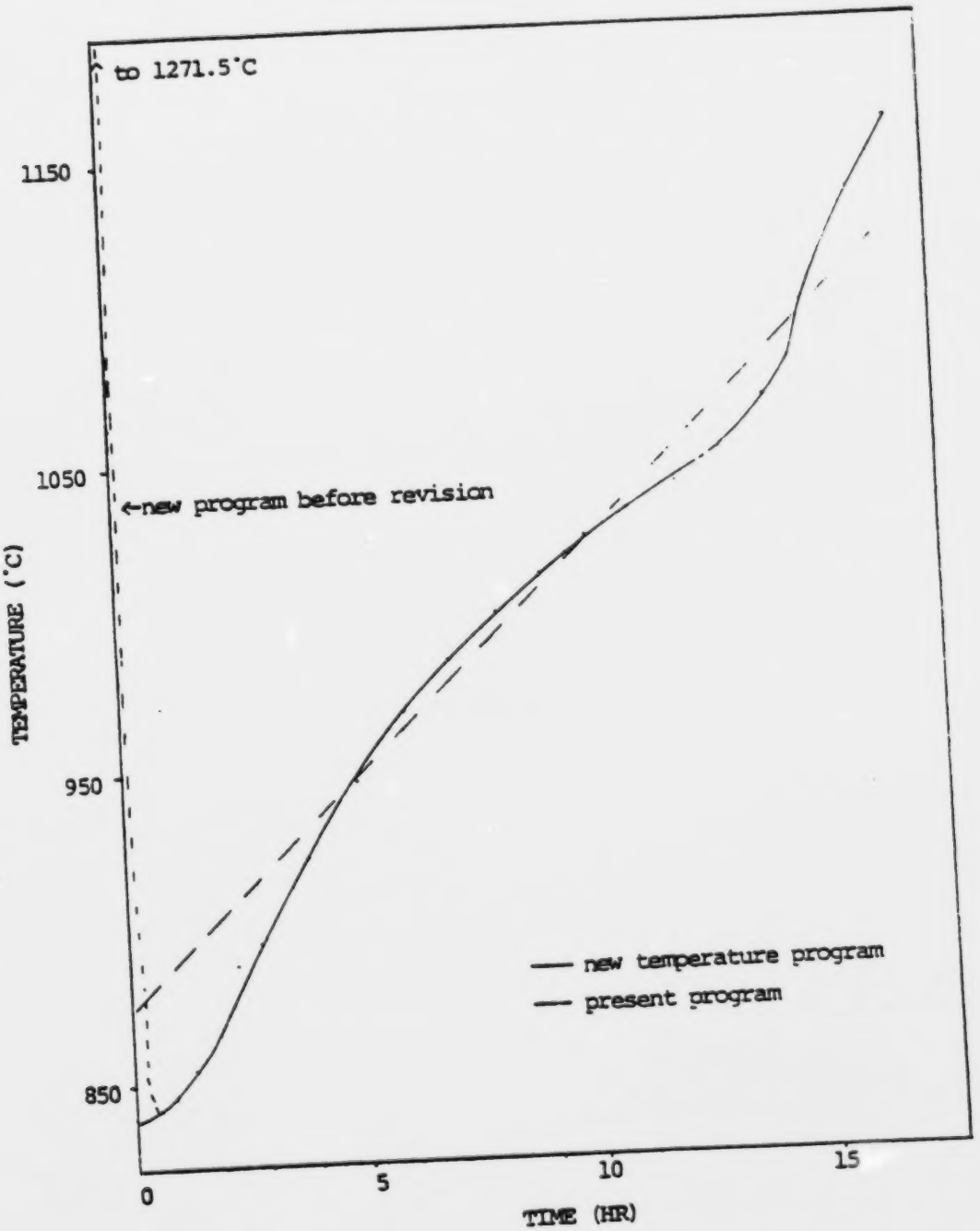

Fig. 2 - Comparison of present linear program and program derived from model for the carbolite oven

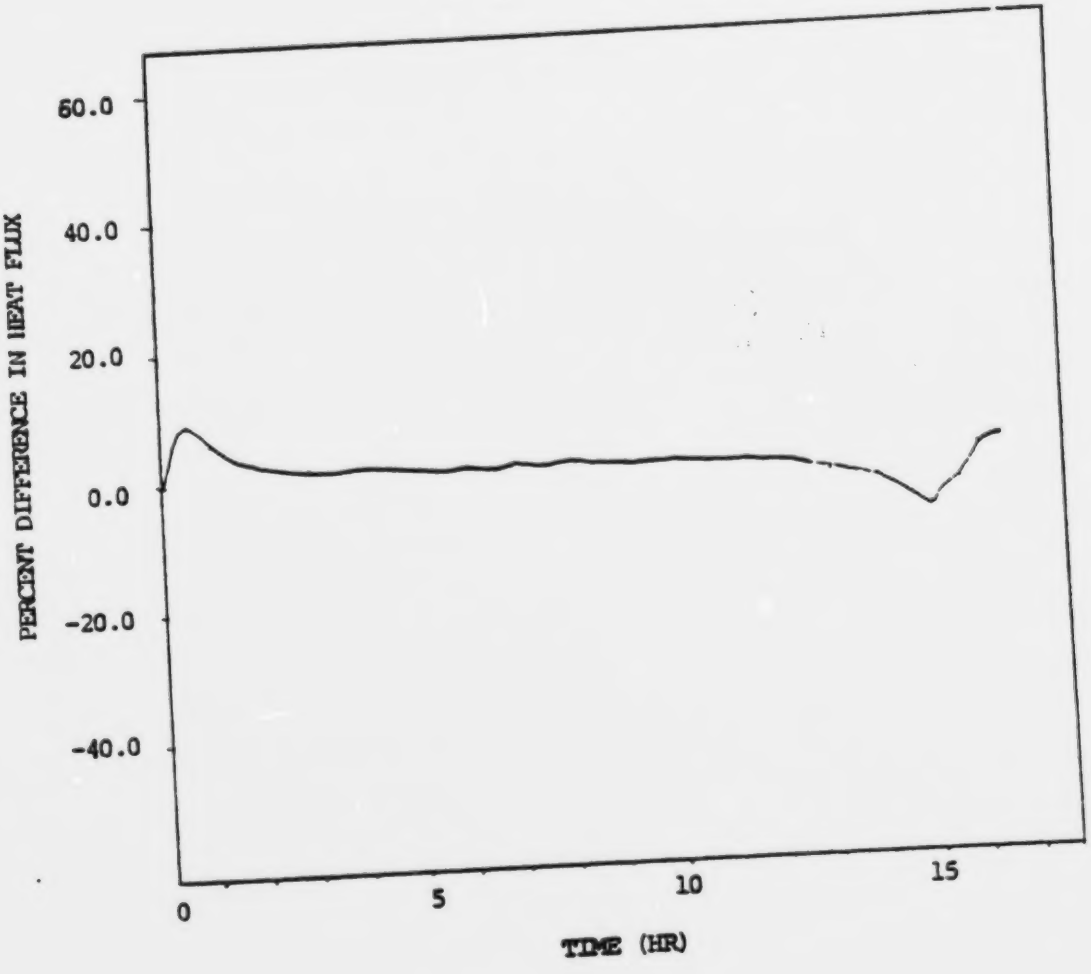

Fig. 3 - Comparison of heat flux for new program for carbolite and typical industrial oven as predicted by model

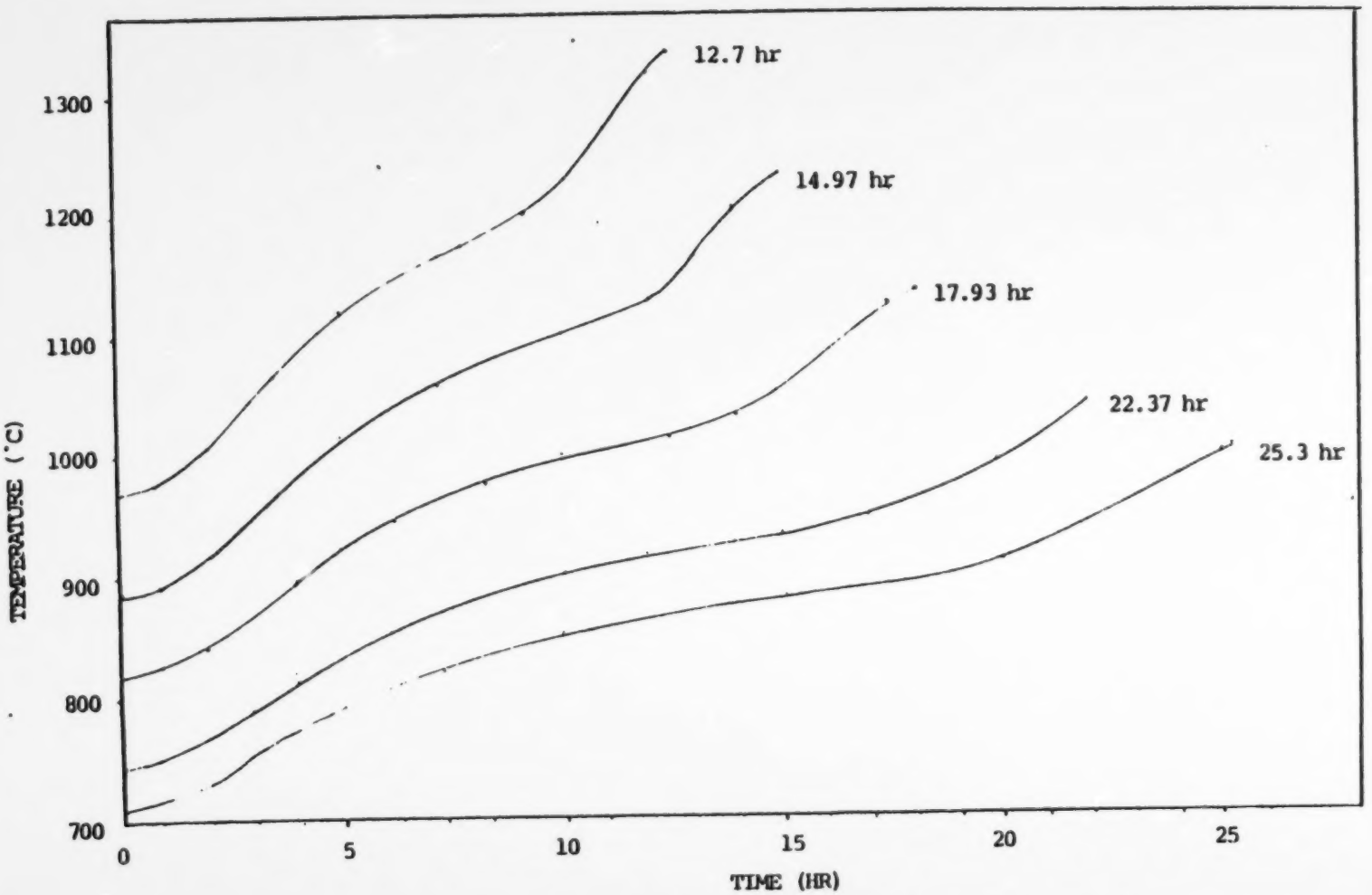

Fig. 4 - New temperature programs for the Carbolite oven. Times to 900°C plus 3h.

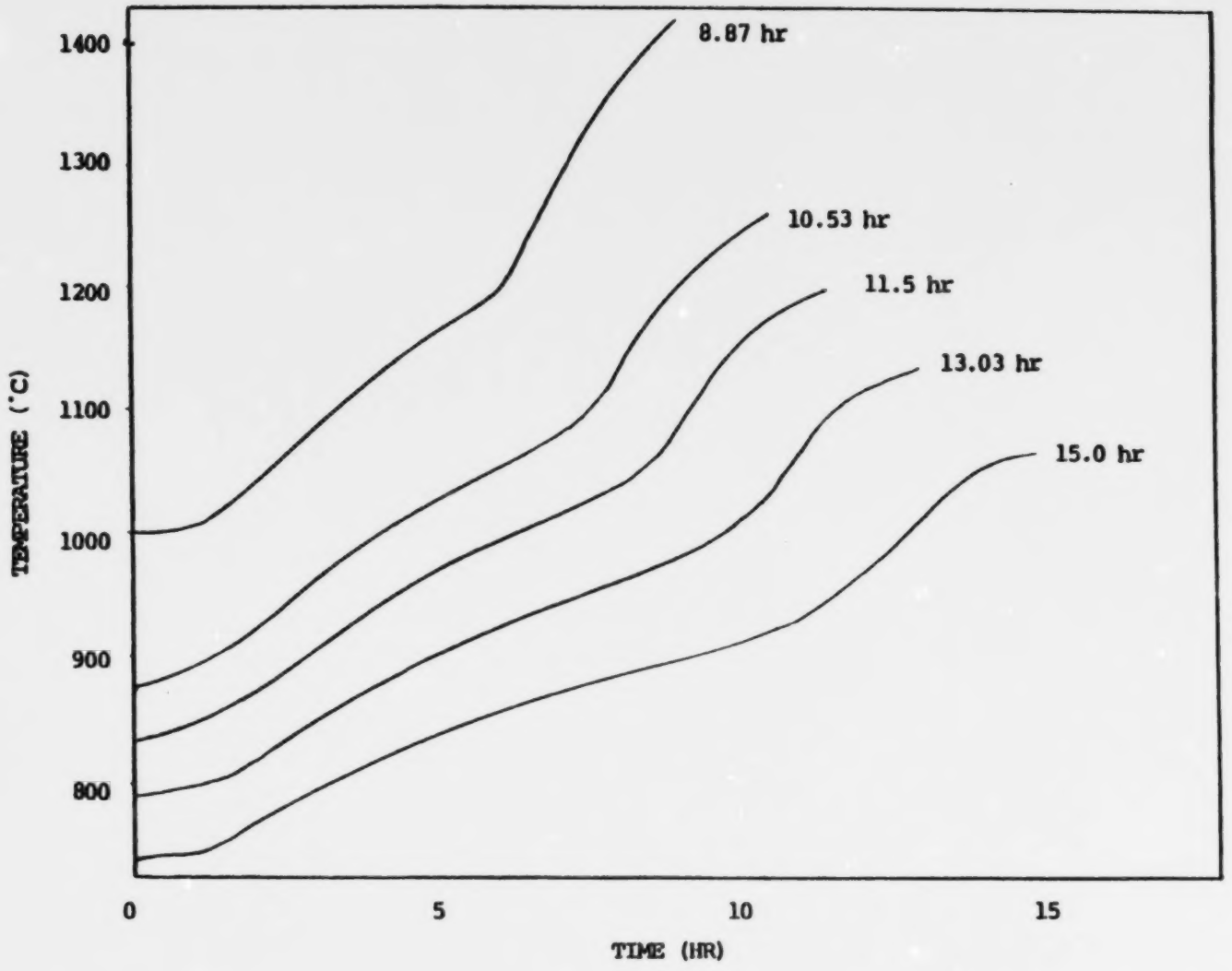

Fig. 5 - New temperature programs for Ottawa 310-mm oven. Times to 900°C plus 3h.